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US Army Research Laboratory

An Analysis of the Far-Field Radiation Pattern of the Ultraviolet Light-Emitting Diode (LED) Engin LZ4-00UA00 Diode with and without Beam Shaping Optics

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NOTICES

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14. ABSTRACT

This report describes the measurements of the far-field radiation pattern of a LED Engin LZ4-00UA00 10-W ultraviolet (UV) light-emitting diode (LED), with and without beam shaping optics. This LED has 4 emitters arranged in a square pattern that are off-center from the optical axis of the LED internal lens. These measurements were made to compare the far-field spatial projection of LED light, specified by the lens manufacturer, with measurements. This analysis found that the far field illumination of the LED itself is not spatially flat, but does not decrease by more than 50% across the 50° by 38° field of measurement used in this analysis. The lens transmits only 20% of the UV LED's peak power and its far-field radiation pattern is about 44° by 25°, the outer boundaries of this region being 50% of the maximum value. Transmission improvements using other polycarbonate material are discussed.

15. SUBJECT TERMS

Lens, light-emitting diode, LED, ultraviolet

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1. Introduction

The US Army Research Laboratory (ARL) is involved in basic research involving optics using emitters at various wavelengths. This report analyzes a LED Engin LZ4-00UA00 ultraviolet (UV) light emitting diode (LED) used with a Carclo 10395 elliptical ripple linear total internal reflection (TIR) Fresnel optic. This Fresnel optic used is specified to reshape visible light. The goal is to determine if the lens can be used to reshape UV light, as well. An analysis is performed using the manufacturer-specified wavelength emission of the UV LED and the spectral transmission of the lens near the LED emission wavelength. The far-field spatial distribution of the LED, with and without a lens, is also analyzed, along with the UV transmission of the lens.

2. Methods, Assumptions, and Procedures

2.1 Assumptions

It is assumed in this work that the spectra of the LED, the Lexan LS2 polycarbonate, and the ThorLabs FES0450, 450-nm shortpass filter are correct, as specified in company and online documentation.

2.2 LED Wavelength Specification and Lexan LS2 Polycarbonate Lens Transmission Characteristics

Figure 1 shows the spectral emission of the LED Engin LZ4-00UA00 LED (blue curve) and the spectral transmission of the Lexan LS2 polycarbonate (orange curve), which is used in the Carclo 10395 elliptical ripple linear TIR lens. The combined results of the UV light from the LED passing through the polycarbonate lens is shown in the gray curve. The polycarbonate, which has the trade name of Lexan LS2, is manufactured by Sabic, and reduces the transmission of the LED by 60%.

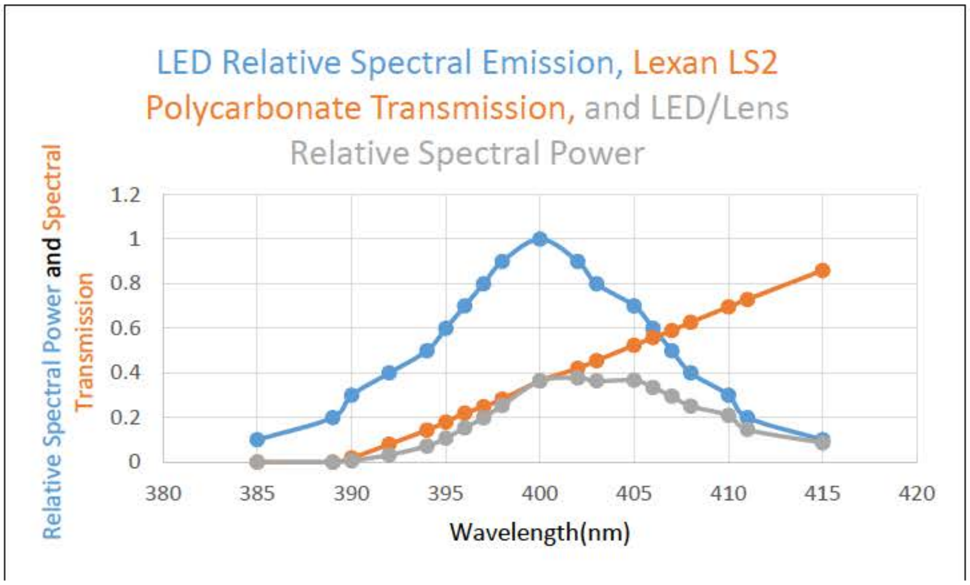

Fig. 1 Transmission of Lexan LS2 polycarbonate near 400 nm

The LED emission starts at 385 nm, which is below the cutoff of the polycarbonate, and ends at 415 nm, where the polycarbonate transmission is at a maximum value of about 83%. Since the LED emission is symmetric about 400 nm, the nearly linear polycarbonate transmission spectra, from 390 to 415 nm, causes an asymmetric spectrum (the gray curve) as the light from the LED is transmitted through the polycarbonate lens.

2.3 Laboratory Procedure

Figure 2 shows the laboratory equipment that was used to make the measurements of the far-field radiation pattern of the LED and lens. The LED is mounted on an aluminum block, which acts as a heat sink. The heat sink is necessary because the LED's power is 10 W and it is necessary to dissipate this energy so that the LED is not damaged. The LED is mounted on a 1-channel, standard star metal core printed circuit board (MCPCB) and the MCPCB is mounted on an aluminum block of metal that acts as a heat sink. The polycarbonate lens is mounted in a lens holder (white in Fig. 2) and then attached to the MCPCB using thin wire.

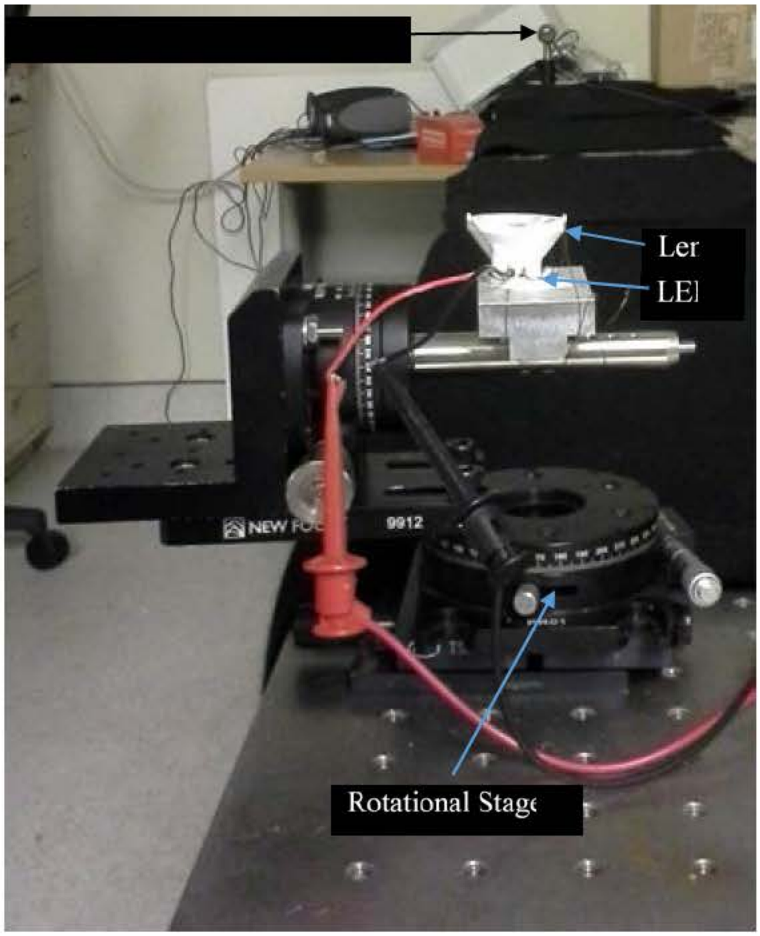

Fig. 2 **Laboratory setup to measure the far-field radiation pattern of an LED**

A ThorLabs FES0450 450-nm shortpass spectral transmission filter, whose spectral transmission is shown in Fig. 3 and identified in the laboratory analysis by an arrow in Fig. 2, is used to eliminate wavelengths greater than 450 nm. This filter transmits the radiation from the LED or LED/lens combination to a ThorLabs S120VC silicon standard photodiode power sensor, which is sensitive in the 200–1100 nm range.

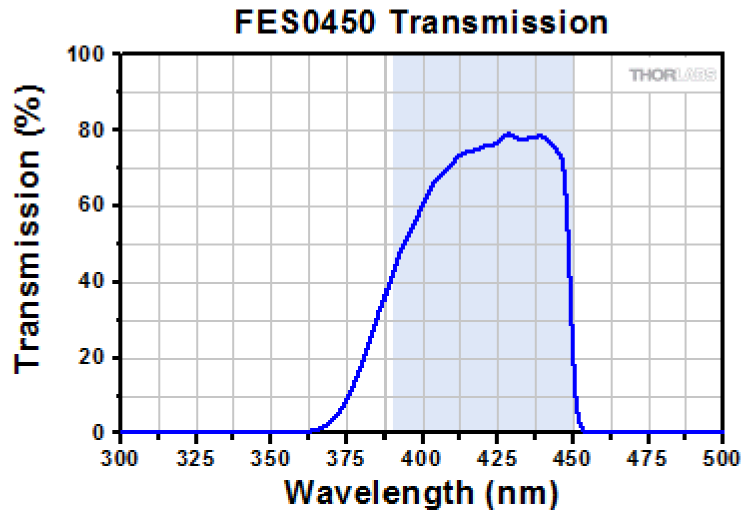

Fig. 3 **Spectral characteristics of the 450-nm shortpass filter**

The sensor is shown mounted on an optics table in Fig. 2 along with 2 rotational stages that move the LED in 2 orthogonal directions about vertical and horizontal axes. With the LED emission directed at the sensor, the ranges of rotation about the vertical axis and horizontal axes are 50° and 38°, respectively.

Measurements were made manually by systematically moving the rotation stages in increments of 2°, creating a matrix of 520 measurement values. Two sets of measurements were made using the LED and the LED with the lens. The measurements were made starting with the far-left column, then taking measurements every 2° from the top to bottom rows of the column. The rotational state causing horizontal motion (rotation about the vertical axis) was then moved 2° so that the next column of data could be measured.

A calibration measurement was made before each column of data was acquired. This was necessary because as the LED temperature increased, the radiant flux decreased. By moving the rotational stages to the same angular position (the center of the illumination field pointed at the sensor) prior to acquiring measurements of a column, the changes in the ThorLabs photodiode power sensor could be monitored and used to calibrate the column of data. The changes in the calibration measurements were added or subtracted to a column of data to compensate for the LED temperature changes.

3. Results and Discussion

Analyses of the far-field radiation pattern of the LED and the LED/lens combination are shown in Figs. 4 and 5. Notice that in Fig. 4, the intensity is not uniform. This is expected because the LED has 4 emitters that are mounted off-center from the optical axis of the integrated glass lens that is part of the LED package. The maximum measured power in Fig. 4 is 8.25 µW. Each colored band in Fig. 4 graphically shows a change of 0.5 µW (the center magenta band records 8–8.5 µW ranges). The specified viewing angle of the LED, defined as the off-axis angle where the radiant power is one-half of the peak value is 37°. The measured viewing angle is greater than 35°, since the navy blue band in the upper-right corner records values of 5–5.5 µW, which is greater than the 8.25/2=4.125 µW value of one-half the maximum recorded value.

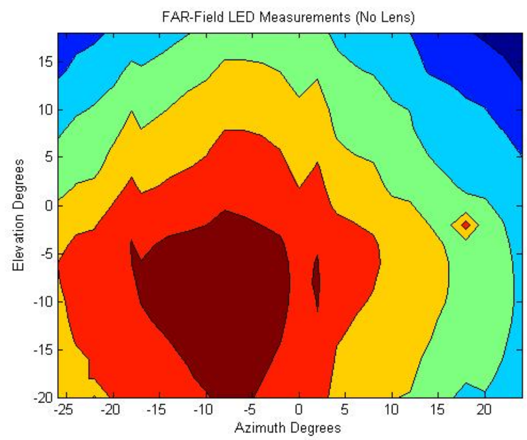

Fig. 4 LED far-field radiation intensity

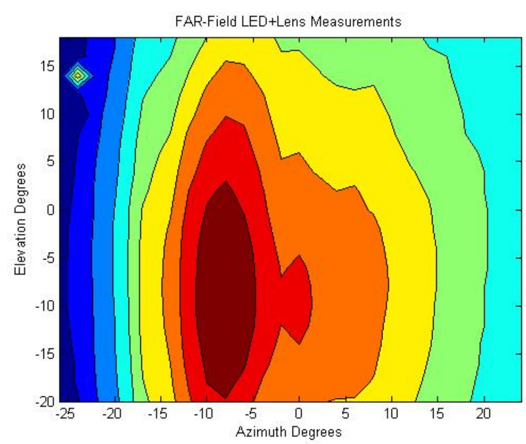

Fig. 5 LED/lens far-field radiation intensity

The contour bands of Fig. 5 graphically show a change of 0.2 µW, and the maximum value, in the magenta band, is 1.3 µW. The attenuation of the beam is primarily due to the Lexan LS2 polycarbonate that is used, which does not fully transmit the LED spectra, which are symetrically centered at 400 nm. The manufacturer specified far-field beam projection is 46° x 21°. This compares favorably with measurements of the Fig. 5 data, where the edge of the far-field radiation pattern is one-half of the the peak value. Using these criteria, the measured far-field beam projection is 44° x 25°, which closely matches the 46° x 21° far-field beam projection of the lens specified by the manufacturer.

4. Conclusion

Polycarbonate lenses are good solutions for several experiments underway here at ARL; however, care must be taken to select lens materials that match spectral requirements. The lens analyzed in this report has a useful far-field projection, but does not pass UV light near 400 nm. An inexpensive solution to this problem, discussed with the lens' manufacturer Carclo, is to use a different polycarbonate material in the manufacture of the lens. Lexan 1125 polycarbonate, shown in Fig. 6, would provide good transmission characteristics from 350–1100 nm. Carclo recently communicated that the price of such a lens would not increase the price by more than a factor of 2.

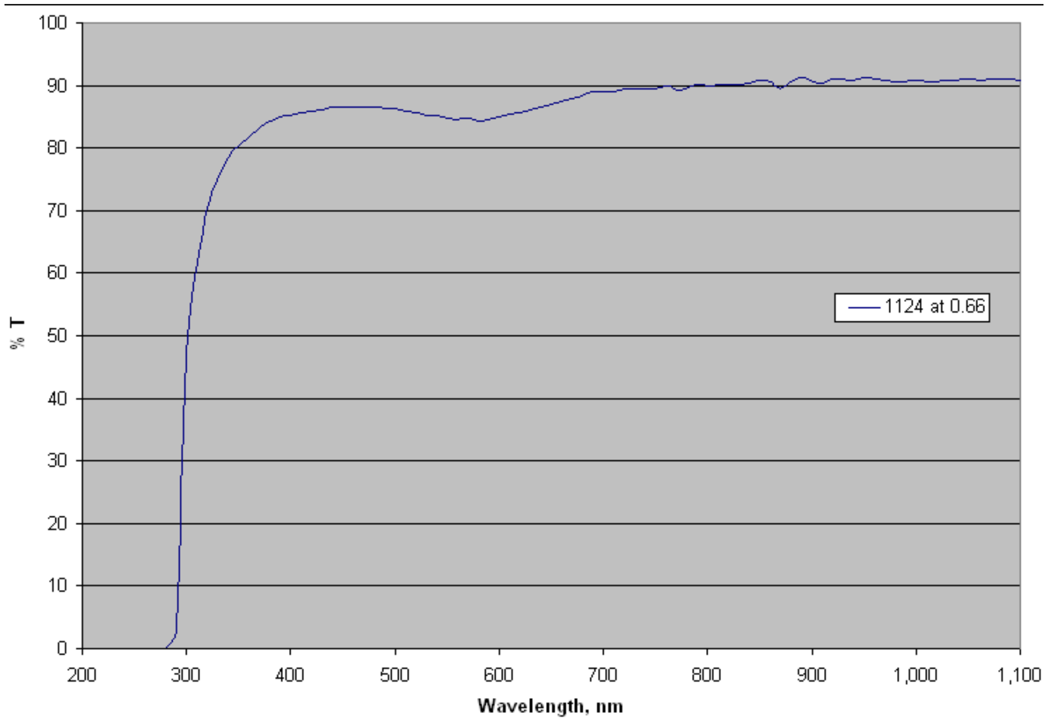

Fig. 6 Transmission characteristics of Lexan 1125

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